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[Note]

Variations in Vertical Location of Kootenai River White Sturgeon during the Prespawn and Spawning Periods

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Abstract.—Our objectives were to determine the general water column habitat use of Kootenai River white sturgeon *Acipenser transmontanus* during the prespawn and spawning periods and to determine the degree of their benthic existence. Depth-sensitive radio transmitters were attached to five male and four female white sturgeon and were periodically monitored day and night from April through June 2001. A total of 297 radio contacts were made, of which 209 included the depth of the river. One fish was not used for statistical analysis because its behavior was often modified by the presence of our boat. Of the 209 contacts, 75% (156) were made within the bottom one-third of the water column. Mean depth of the fish during the daytime prespawn and daytime spawning period was different (9.7 and 6.5 m, respectively), and the distribution between these two periods was significantly different. Some of the variation was likely due to the deeper habitat of the daytime prespawn staging reach compared with that of the daytime spawning period location (12.6 and 7.7 m, respectively). White sturgeon used a variety of locations throughout the water column, were closer to the river bottom during the spawning period, and were much more mobile during the spawning period than we previously believed. We were also able to chart some white sturgeon as they gradually cruised the contour of the river bottom several meters from the substrate yet paused momentarily. Although depth-sensitive transmitters were well suited to further defining some white sturgeon behavioral characteristics, they lacked the precision to achieve instantaneous locations.

Findeis (1997) described acipenserids as being distinctive in morphology and behavior, contributing to their benthic habitats and behavior. Findeis (1997) went further to describe known phylogeny and "benthic cruising" by acipenserids as an adaptation during their evolution for foraging focally from the substrate and for locomotion. However, these fishes never achieved the extreme benthic specialization exhibited by some fishes (e.g., flattened bodies, extreme camouflage, and stationary behaviors). Findeis' (1997) description of acipenserid benthic behavior motivated our interest in examining Kootenai River white sturgeon *Acipenser transmontanus* behavior and distribution in the water column. White sturgeon have a benthic body form characterized as elongate and somewhat cylindrical in shape, and have a large, protrusible ventral mouth (Simpson and Wallace 1982). It is common knowledge that white sturgeon and other acipenserid sturgeon can be seen at the water surface and occasionally breach through the surface of the water or jump. Similar behavior is hypothesized to be a form of communication for Gulf sturgeon *A. oxyrinchus desotoi* (Sulak et al. 2002). In addition, there is limited evidence suggesting that white sturgeon may spawn throughout the water column, including near the surface (Parsley et at. 1993; Paragamian et al. 2001).

Ultrasonic telemetry and radiotelemetry have proven to be useful tools in determining life history characteristics of Kootenai River white sturgeon as well as other sturgeon populations (Hildebrand et at. 1999; Paragamian and Kruse 2001; Snook et at. 2002; Perrin et at. 2003; Heise et al. 2004). In recent years, depth-sensitive radio and ultrasonic transmitters have become available for application with sturgeon and other fishes. Our primary objectives were not to test Findeis' (1997) hypothesis but to use depth-sensitive radio transmitters to determine Kootenai River white sturgeon water column habitat use during the prespawn and spawning periods and to determine the degree of their benthic lifestyle.

Study Area

The Kootenai River is in the upper Columbia River basin. The river originates in Kootenay National Park (note that U.S. and Canadian spellings for Kootenai are different), British Columbia (BC), Canada, flows south into Montana, and turns northwest at the site of Libby Dam. As the river flows west through the northeast corner of the Idaho Panhandle (the canyon reach), it shifts to the north at Bonners Ferry, Idaho (river kilometer [rkm] 246) and enters Kootenay Lake (rkm 120), BC. The Kootenai River joins the Columbia River

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TABLE 1.-Fish number, number of complete contacts, mean depth and position (±SD), and measurements of nine white sturgeon tagged with depth-sensitive radio transmitters in the Kootenai River, Idaho, March-June 2001. Abbreviations are as follows: FL = fork length; TL = total length; F = female; and M = male.

Fish number	Sex	FL (cm)/ TL (cm)	Weight (kg)	Number of contacts	Mean depth of fish (m)	Mean depth of river (m)	Mean distance from river bottom (m)	Mean relative position
1[a]	F	178/194	49.25	5	4.8 ± 1.4	6.7 ± 1.6	1.9 ± 2.0	0.7 ± 0.2
2	M	155/170	30.05	10	9.5 ± 4.2	9.5 ± 2.8	0.6 ± 0.9	0.9 ± 0.1
3	M	199/233	58.25	8	8.3 ± 4.7	11.9 ± 3.8	3.7 ± 3.2	1.0 ± 0.1[b]
4	M	132/150	19.25	16	6.8 ± 1.8	8.1 ± 2.5	1.5 ± 1.9	0.8 ± 0.2
5	M	167/186	37.25	8	6.9 ± 2.0	10.4 ± 1.7	3.5 ± 2.0	0.7 ± 0.2
6	F	185/215	57.25	26	7.4 ± 1.9	8.1 ± 1.9	0.7 ± 1.6	0.9 ± 0.2
7	F	196/229	77.25	31	5.7 ± 2.0	7.6 ± 2.2	1.9 ± 1.6	0.8 ± 0.2
8	M	156/175	33.25	32	12.5 ± 6.4	14.3 ± 7.5	2.2 ± 2.3	1.0 ± 0.2
9	F	186/215	57.25	73	5.7 ± 2.5	8.5 ± 3.6	2.9 ± 2.8	0.7 ± 0.2
Total or mean				209	6.8 ± 3.8	9.4 ± 4.6	2.2 ± 2.4	0.8 ± 0.2

[a] Depth information on this fish was not used in the statistical analysis.
[b] Mean relative location was 0.95 but rounded up to 1.0.

at Castlegar, BC. From its origin to Bonners Ferry (rkm 246), the river is high gradient but low gradient downstream to Kootenay Lake (Paragamian et al. 2001). Most Kootenai River white sturgeon are found downstream of Bonners Ferry. Our primary study reach for this investigation was from rkm 203.0 to 246.0 (the staging [rkm 203-216.5] and spawning reach [rkm 228-246]), the upstream portion of the low-gradient, meandering reach. The staging reach has several wide and deep (about 25 m) meander bends with current velocities of less than 0.5 m/s in which white sturgeon are commonly found prespawn. Both reaches have a sub--strate primarily composed of sand and fine sediment.

Kootenai River white sturgeon have a short, two-step migration pattern (Bemis and Kynard 1997), moving from the river in BC and Kootenay Lake to staging locations in Idaho during fall and spring and later to the spawning reach (Paragamian and Kruse 2001). After spawning, white sturgeon soon move downstream to the river in BC or to Kootenay Lake (Paragamian and Kruse 2001). Most fish appear to spend a greater portion of their life in the lake (Paragamian and Kruse 2001).

Methods

White sturgeon were captured in staging areas with setlines and rod and reel during the months of March and April 2001 (Paragamian and Kruse 2001). Fork length and total length were measured (to the nearest centimeter) in addition to weight (in kilograms). If fish were at least 110 cm in fork length they were sexed according to the methods of Conte et al. (1988).

Depth-sensitive radio transmitters and ultrasonic transmitters were attached to white sturgeon expected to spawn during the spring of 2001 (Table 1). Radio and ultrasonic transmitters were attached to opposite sides of the dorsal fin base by passing stainless steel aircraft cable through two incisions created by sterilized surgical needles. One 12-in length of cable was threaded through two holes on the ultrasonic tag (Sonotronics, Tucson, Arizona; Model EMT-01-2), the body wall via the surgical needles, and two holes on the radio tag. The cable was overlapped on the back of the radio tag and secured using aluminum cable sleeves. The ultrasonic tag was 8.0 cm in length, 1.8 cm in diameter, weighed 9 g, and operated at 75 kHz. The depth (up to 25 m) of the Kootenai River required us to use ultrasonic tags to locate fish. We used Advanced Telemetry Systems (Isanti, Minnesota) Model F2130(2) depth-sensitive radio transmitters that were flat in shape, 6.4 cm in length, 2.6 cm wide, 1.0 cm thick, and weighed 69-79 g. They had a pulse rate of 30-70 pulses per minute and a life expectancy of 440 d. Depth-sensitive radio transmitters are pressure responsive: the depth of the tag can be determined by the pulse frequency, with the frequency increasing with increasing depth. A stopwatch was used to determine the number of seconds for 10 pulses to transpire, which gave a period reading. The period reading was multiplied by 100 to give us a reading in milliseconds. Three readings were made taking 30-90 s, and averaged. The average recorded pulses were entered into a regression equation, and the estimated transmitter depth was calculated. The manufacturer prepared a regression equation for each radio after calibration in a pressure chamber. Prior to deploying depth-sensitive transmitters on sturgeon, we field examined the transmitters for

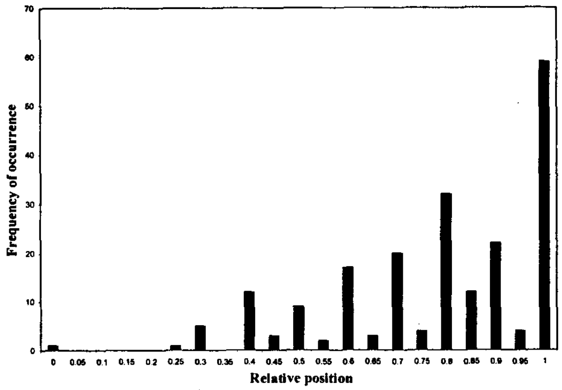


FIGURE 1.-Frequencies of relative position in the water column of Kootenai River white sturgeon (*N* = *209*) with depth-sensitive radio transmitters, April 8 through July 17, 2001. Locations are at 0.05 class intervals; 1 = the riverbed, 0 = the river's surface.

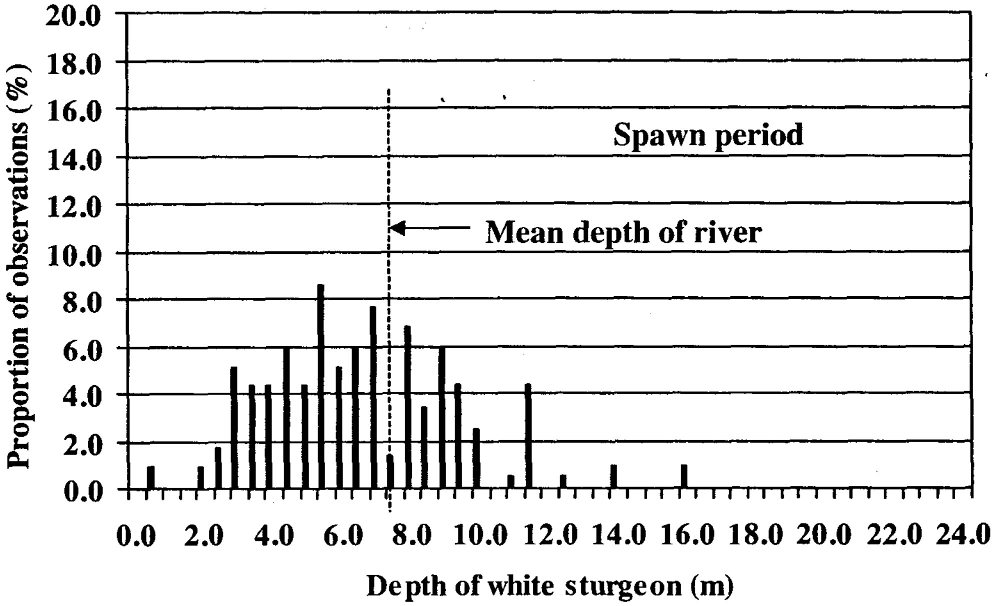
general precision by lowering them to known depths and found them to be well within 0.5 m of the estimated depth. We believed this was satisfactory for our general studies.

Fish were located daily by boat, and on occasion individuals were followed for longer periods of time (i.e., up to 8 h) during daytime and nighttime hours, while individual records were made at varying time intervals. Few contacts were made at night in the staging reach. After fish moved from the staging reach to the spawning reach, each day was divided into three 8-h work blocks (0600—1359, 1400—2159, and 2200—0559 hours). Fish were monitored for approximately two-thirds of the 21 blocks each week. Selection of each block was determined by a table of random numbers (Snedecor and Cochran 1989). Later we divided the blocks into four periods, including two crepuscular periods (dawn and dusk; Paukert et al. 2004). The period of dawn was delineated as 2 h before sunrise to 2 h after sunrise. Dusk was 2 h before sunset to 2 h after sunset. Day and night were the time periods in between, and, because of the approach of summer, the length of day gradually increased. Once fish were located with ultrasonic telemetry, a Motor Guide electric trolling motor was used to approach fish from directly above. Upon determining the exact location with ultrasonic telemetry, radio pulse period was measured and recorded. The fish location was simultaneously verified, and corresponding river depth at the location was then determined using an Eagle Fisheasy depth finder and recorded to the nearest foot (later converted to meters). We also frequently marked and graphed sturgeon with a Lowrance X15A depth recorder for depth verification. For descriptive behavior we followed some white sturgeon for serial locations as they cruised for extended periods of time yet paused momentarily, allowing us to collect data to estimate their depth.

We examined three general aspects of white sturgeon habitat use in the water column during the prespawn and spawning periods: (1) fish and river depth; (2) a general index of fish location relative to the river bottom (relative location) so we could compare the prespawn and spawning periods (calculated as the proportion of sturgeon depth to the depth of the water [e.g., a fish on the bottom would be 1.0, middepth would be 0.5, and the surface would be 0.0]); and (3) distribution of fish locations within the water column. The two-sample Kolmogorov—Smirnov test (Wilkinson 1990) was used to compare the distribution of (1) daytime depths during the prespawn period with daytime depths during the spawning period, (2) daytime relative location in the water column during prespawn period with daytime relative location during the spawning period, and (3) daytime spawning period fish depth with combined dusk and dawn spawning period fish depths. For the Kolmogorov—Smirnov test, we treated the serial locations of white sturgeon as clusters and calculated a weighted mean for each of the serial locations, thus reducing our total sample size. The weighted mean was then treated as a single location and included with the remaining single locations for analysis. The spawning period was based on an estimated initial spawning date of May 15, a date during which all tagged females were in the spawning reach and white sturgeon eggs had been collected shortly thereafter (Paragamian et al. 2003). If white sturgeon were later relocated downstream of the spawning reach, they were included with the prespawn locations because it was assumed they had completed spawning.

Results and Discussion

We attached depth-sensitive radio transmitters to a total of nine white sturgeon (five males and four females) and detected a total of 297 combined locations with hovering or cruising fish. Of this total, 209 contacts included both the estimated depth of the fish and the estimated depth of the river; the locations without a river depth were omitted (Table 1). Records for individual sturgeon with river depth ranged from 5 to 73. The average depth of fish (N = 209) was 6.8 ± 3.8 m, with a corresponding mean water depth of 9.4 ± 4.6 m during both the prespawn and spawning periods



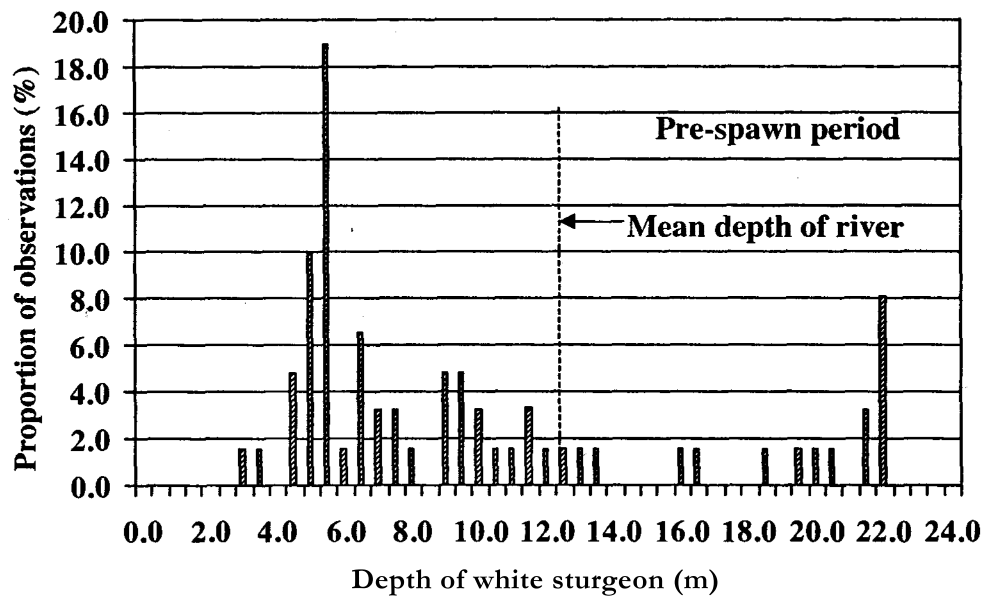


FIGURE 2.–Depth distribution and proportion of observations of Kootenai River white sturgeon during the prespawn period (lower panel) and spawning period (upper panel), excluding serial observations. Mean depth of the river at white sturgeon locations is indicated by dashed lines, and depth is in 0.5-m class intervals.

(Table 1). Many other contacts were made, but we were unable to get precise measurements for the fish location.

One white sturgeon with a depth-sensitive transmitter (number 1) demonstrated evidence of acute sensitivity to an approaching boat by modifying its position. For example, on most occasions when our boat approached white sturgeon 1, by as far as 30 m, she immediately moved away from the boat. As a result, this fish was not used for statistical analysis (N = 5, thus leaving N = 204). The remaining white sturgeon allowed us to move above them with our electric motor and were apparently undisturbed.

Our results indicated that Kootenai River white sturgeon were not exclusively benthic, and when we located them as they cruised they often followed the contour of the river bottom cruising 2–

3 m (mean = 2.2 ± 2.4 m) above. Yet about 75% (N = 156) of the total contacts were made in the bottom one-third of the water column (Figure 1). Some fish were located well off the bottom, and, in one extreme case, a white sturgeon was located just below the surface within 0.5 m from shore and in less than 2 m of water.

The Kolmogorov–Smirnov test suggested the daytime depth distribution of white sturgeon during the prespawn period was different from that during the daytime spawning period (P = 0.001) as more fish were found closer to the river bottom during the spawning period than during the prespawn period (Figure 2). We detected a weak difference in the distribution of relative location in the water column (P = 0.030), relative locations of 0.77 (SE = 0.03) and 0.79 (SE = 0.02) during the prespawn and spawning periods, respectively. The mean depth of the fish for the daytime prespawn period was 9.69 m (N = 63, SE = 0.74), while that for the daytime spawning period was 6.46 m (N = 97, SE = 0.25). The differences in the depth of white sturgeon during the prespawn period compared with that of the spawning period is most likely explained by the deeper habitat of the prespawn staging reach compared with that of the spawning reach (12.60 m [N = 63, SE = 0.78] and 7.67 m [N = 97, SE = 0.27], respectively). The crepuscular mean depth (N = 17) of white sturgeon was 6.89 m (SE = 0.65), with a relative location in the water column of 0.75 (SE = 0.5), but we could not detect differences when compared with daytime spawning period records. This analysis was probably limited by the small sample size of crepuscular locations, resulting in a higher variance. Our night time samples were even smalller (N = 2).

Although depth-sensitive transmitters were well suited to further define some white sturgeon behavioral characteristics, thereby satisfying an important objective, they lacked the precision to achieve instantaneous locations. First, white sturgeon appeared much more mobile than expected, and a sampling bias may have been introduced because we were compelled to eliminate the data points of many cruising fish if they did not pause. Furthermore, rapid vertical movement of cruising sturgeon often made it difficult to get precise locations because it took 30–90 s to get an average depth. A third source of difficulty was at night when the river was more challenging to navigate and the mobility of the fish did not diminish. As a result, we were unable to include accurate nighttime documentation of prespawn and spawning period locations for many other white sturgeon contacts. Since this was a general study of Kootenai River white sturgeon, we suspect results for other sturgeon populations may differ. Bemis and Kynard (1997) suggested acipenseriforms did not have a common life history, and variations within and between species is the rule, not the exception.

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